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ELECTROMAGNETIC INSPECTION OF WIRE ROPES USING SENSOR
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ELECTROMAGNETIC INSPECTION OF WIRE ROPES USING SENSOR ARRAYS

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Quarterly Progress Report for Period
16 December 1983 - 15 March 1984

Prepared for

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SUMMARY

During the time period from 16 December 1983 thru 15 March 1984 we achieved the following:

- We performed an experimental investigation of the magnetic flux patterns in the magnetizer-sensor arrangement and in the wire rope. This investigation led to a better understanding of the previously mentioned "echo effect".
- We investigated a number of different magnetizer-sensor configurations using split-pole arrangements and various pole pieces with different geometries. At the present time, it appears that the use of longer and narrower pole pieces and elongated magnet geometries significantly reduce the previously mentioned "remagnetization effect".
- We modified our coil simulation program to include the interaction of coils and magnetizer for our new loss-of-metallic-area instruments. The simulated results are in excellent agreement with the above mentioned experimental results. The simulation program now allows an accurate prediction of the instrument performance. Unfortunately, the simulation will not predict the signal-to-noise ratio at the present time.
- Based on the above experimental and theoretical investigations, we initiated the design and manufacture of a new bigger prototype instrument. A first design of this new instrument is now complete.
- The manufacturer of the computer analog/digital interface board finally has corrected his software problems. Programs can now be written in Compiled Basic. We implemented some simple statistical programs which can determine the worst sections of a wire rope.
- The cassette tape recorder was delivered. Unfortunately, the signal-to-noise ratio of recorded signals was not satisfactory. The recorder was therefore returned to the distributor. Instead, we designed our own frequency modulation circuitry. This circuitry allows the use of any commercially available stereo recorder to record the test signals with a completely satisfactory signal-to-noise ratio.
- The proposed speed sensor circuitry is not feasible. While the circuits work well in principle, we were not able to sufficiently improve the accuracy of this scheme, in spite of a significant effort. We are presently considering some simple alternative methods for sensing rope speed.

PROGRESS

With respect to the tasks formulated in the Phase II Proposal, the following was accomplished:

1. Leakage Flux Method for the Quantitative Characterization of Localized Defects

Task 1.1: Improve Existing Signal Conditioning Circuitry

See Task 2.3

Task 1.2: Design, Build and Evaluate Improved Sensors

See Task 2.2

Task 1.3: Implement Extended Automatic Defect Identification Method

See Task 2.3

2. Main Flux Method for the Quantitative Characterization of Extended Defects

Task 2.1: Design and Build Magnetizer Assembly

As mentioned previously, for main flux instruments the shape of the magnetizer drastically affects the test signal, and the design of coils and the magnetizer can no longer be treated separately and independently. Magnetic flux patterns are very complex.

To study the flux patterns in the magnetizer, we built experimental machines with additional sense coils in the pole pieces. These experiments gave a clear explanation of the echo effect.

An explanation of the phenomenon is illustrated in Figure 1. The figure shows the magnetic flux patterns. In particular, note the magnetic stagnation point under the pole pieces where the magnetic flux reverses directions. Without changing any signals, the outer part of the sense coils could be replaced by the equivalent coils indicated by dotted lines in the figure. This becomes immediately plausible because the outer coils could be moved to the position of the equivalent coils without cutting any flux lines, i.e., without inducing any additional voltages in these coils.

The echo effect can now be explained. Upon approaching the instrument, any irregularity in the rope is first sensed by the equivalent coils (or equivalently, by the outer part of the sense coils). This causes the first "echo". The discontinuity is then sensed by the inner part of the sense coil which gives the actual flaw signal. The outer part of the sense coils senses the discontinuity again while moving away from the instrument. This causes the second "echo".

Based on these investigations, we modified the existing coil simulation program to include the echo effect. The simulation of split pole pieces is also possible. Simulated results are in excellent agreement with the experimental findings.

Encouraged by a computer simulation, and despite the failure of a first attempt (as reported previously), we made another effort at eliminating the echo effect by placing the outer return coils into a magnetically neutral zone as shown in Figure 2. In this case the magnet assembly was split into two pieces and the outer return coil was placed into the magnetically neutral zone between the two magnetizer pieces as shown in the figure. While these experimental results were completely consistent with the simulated results, the signals were again as noisy as in the previous first attempt. This noise is caused by the rapid reversal of the magnetic flux in the magnetically neutral stagnation zone. Unfortunately, the simulation gave no indication of this behavior. As stated previously, the signal-to-noise ratio of our new main flux instruments is significantly better than that of any other instrument. Therefore, we decided to postpone further attempts to improve the signal-to-noise ratio by eliminating the echo effect as described above.

The experiments indicated that the geometrical arrangement of the permanent magnets in the magnetizer assembly has a very strong effect on the previously mentioned remagnetization phenomenon. This effect is not completely understood. However, it appears that, to minimize the remagnetization effect, the permanent magnets should be arranged along a longer section of the rope. This stretched geometrical magnet configuration will establish the magnetic flux in the rope gradually, ameliorating the remagnetization effect.

Based on these findings, we started the design of a new larger instrument which should have a significantly reduced remagnetization effect. A first design of this instrument is now complete.

Task 2.2: Design and Build Main Flux Sense Coils

The design of main flux sense coils can now be considered complete. The present coil design should be sufficient for our further investigations.

Task 2.3: Design and Build Signal Conditioning Circuitry

The speed sensing scheme proposed in the Phase II Proposal is not feasible. The approach works quite well in principle. However, in an actual application sufficient accuracy cannot be achieved. A major problem is that the circuit depends on the intrinsic noise of the rope which in many cases, especially for new ropes, is negligible. Therefore, the proposed approach will now be abandoned. However, we will pursue alternative methods which appear more feasible.

One of these methods, which is very simple and does not require any moving components, allows counting of rope lays. This approach is feasible. It can probably be modified to sense rope speed and position. We will pursue this approach further.

The conventional approach, using a friction wheel and an incremental encoder will also be implemented.

Note that the digital computer can determine the instantaneous rope speed for localized flaws by comparing the LMA and LF signals. For implementing a digital defect identification scheme, this is completely sufficient.

3. Combining Leakage Flux and Main Flux Methods.

Task 3.1: Design, Build and Evaluate Combined Instrument

Separate sensors for leakage flux and main flux sensing are no longer required. The present coils are sufficient to implement the proposed defect identification scheme. Therefore, this task is now considered completed.

4. Digital Processing of Test Signals

Task 4.1: Selection of Digital Signal Conditioning Instrumentation

The TEAC Cassette Tape Recorder was delivered. Unfortunately, the quality of recorded signals was low. Especially objectionable was the deterioration of the signal-to-noise ratio caused by the recorder. In addition, we consider the price of the recorder quite high for this type of equipment. The recorder was therefore returned to the distributor.

Task 4.2: Development of Interfacing Circuitry

Since we could not find a suitable data acquisition cassette recorder, we developed our own frequency modulation circuitry. Using this circuitry, any stereo cassette recorder can now be used for data acquisition. At the present time, we are using a small Radio Shack stereo recorder which, in combination with our interface circuitry, gives excellent results.

Task 4.3: Develop Algorithms for Digital Signal Processing

The manufacturer of the digital-analog interface board for the IBM PC has solved his software problems. Programs can now be written in BASIC and compiled by the IBM Compiler. Work on digital signal processing algorithms has resumed.

We wrote a simple program to determine and locate the worst sections of a rope. Programs like this require large numbers of computations and can run for fairly long time periods, even in their compiled versions. Therefore, we will make an effort to make our future programs as fast as possible, for instance, by using integer arithmetic and DMA transfers whenever possible.

5. Instrument for the Inspection of Wire Rope End Sections

Task 5.1: Develop, Manufacture and Evaluate Instrument for the Inspection of Wire Rope End Sections

A piece of test rope including the socket was purchased. Design of the instrument was initiated.

6. Testing

Task 6.1: Perform Lab and Field Tests

Only lab tests were performed during the reporting period. These lab tests, in connection with the previous comparative field tests, allow a convenient evaluation of the performance of newly developed instrumentation.

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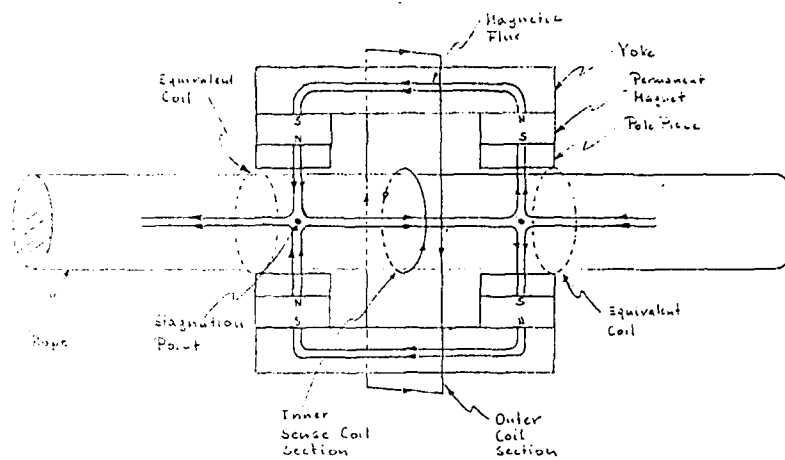


Figure 1: Echo Effect

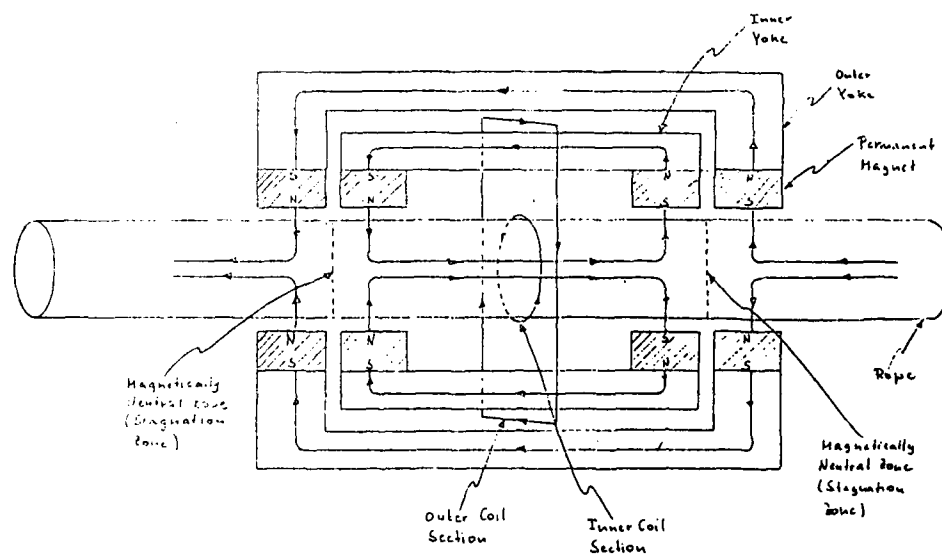


Figure 2: Split Magnet Assembly

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